Autonomous Rover Technology for Mars Sample Return

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Abstract

Planetary rovers enable good sample selection and retrieval for Mars sample return missions. After landing, the rovers search for the best possible scientific samples in the region around a lander, and they return these selected samples to an ascent vehicle that launches the samples into Mars orbit. To streamline the search for, the acquisition, and the retrieval of samples, rover autonomy is a critical technology. This paper summarizes a series of experimental results in the evaluation and demonstration of planetary rover autonomy, with a particular emphasis on rover system technology capabilities under development for a 2005 Mars sample return mission and its precursor missions.

An autonomous system is defined here as one that can execute multiple-command sequences robustly at the remote rover site, without direct intervention by ground controllers while the sequence is being executed. The longer and more complex the task that a given rover can reliably execute by itself, the more autonomous the rover is. Execution of complex tasks with minimal ground control is essential to maximize science return for fixed mission duration, and to compensate for the long time that it takes for commands from Earth to reach their destination on the Martian surface. Three specific autonomous rover operational tasks are described in detail:

Long Range Traverse and Science Acquisition: This tasks involves long distance traverse from one site to another while operating in relatively rocky terrain, under the constraint that the traverse must be executed autonomously with a single command cycle. The sequence includes the deployment of multiple instruments at various steps in the sequence, as well as the acquisition of multiple scientific samples. The experiments investigate the limits of what a planetary rover can do by itself, using technologies in on-board sensing, sequence planning, hazard avoidance, and goal confirmation.

Autonomous Small-Rock Pick-Up: This task illustrates the autonomous acquisition of small rocks, using visual and touch sensors and a rover-mounted micro-arm to achieve the rock pick-up operation. This type of autonomous operation is useful in streamlining the sequence of actions that the rover and its manipulator must take in response to detection of an interesting rock sample that needs to be picked up.

2-Vehicle Surface Rendezvous & Sample Transfer: This sequence demonstrates, in a terrestrial analog experimental scenario, a terminal guidance, approach and rendezvous task that one autonomous rover executes as it comes close to another rover; and as a sample container is transferred from one vehicle to the other. This sequence illustrates techniques in visual target acquisition, on-board sequence planning, and terminal rendezvous operations.

These three rover tasks illustrate experiments and tests with a variety of flight-like rover technology prototypes that are being developed at JPL as precursors to a sample return rover flight system. Experimental data for the three tasks is analyzed quantitatively in terms of suitably defined complexity

metrics for both the tasks, as well as for the corresponding rover actions necessary to accomplish the tasks. This quantitative data serves to illustrate the level of autonomy that is being achieved in each rover operation, and the techniques that are used to achieve this level. Simultaneously, the quantitative metric data illustrates the currently demonstrated autonomous rover technology and the challenges and plans for future development and experimentation.